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THE MICHIGAN MINER

A Monthly Journal devoted to the Mineral Resources of the Peninsular State.

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THE ORIGIN, PROPERTIES AND USES OF SHALE.

By H. RIES,

Special Agent for the State Geological Survey.

Shale, simply defined, is clay which has become consolidated into a hard mass by pressure.

Clay is a familiar material and known chiefly by the curious property which it has of forming a pasty or plastic mass when mixed with water, allowing itself to be molded into any desired shape. It is a fine, aluminous sediment that has been deposited on the bottom of lakes or seas. If nothing else were deposited on the top of this clay sediment before the lake evaporated or became drained, or before the sea bottom was lifted up and became dry land, the material would retain the soft plastic condition that many of our surface clays show. Very often, however, the clay, when deposited in the sea, becomes covered by many feet of other sediments of a different nature, and by the weight of these overlying beds it is pressed and consolidated into quite a firm mass. (That pressure alone will consolidate clay particles is seen when bricks are molded by the dry clay process.)

Sometimes the firmness and hardness of the shale is increased by mineral-bearing waters filtering through the mass and cementing more or less of it together.

Shale thus originates by the consolidation of clay under pressure, and depending on the amount of pressure it has been subjected to and the amount of cementation of the particles that has taken place, we find variations from soft shales that crumble easily under the action of the weather to hard ones so dense and brittle that they appear and ring like slate. Indeed, shale is very commonly and erroneously called slate, especially when associated with coal; slate and shale, however, are two different materials.

Shale being of sedimentary origin was laid down or deposited in layers or beds, and it splits along these layers or planes of stratification. Furthermore, when it is ground up and mixed with water, it becomes a soft, pasty mass like clay.

Slate possesses neither of these properties. It is a rock that has been formed from shale under the action of heat and pressure. These two agents have obliterated the original layers of stratification so that it no longer splits along them, but on the other hand a new direction of splitting has been produced, parallel to which the slate splits evenly and readily. But what is even more important is that, if the slate be ground up and mixed with water, it does not form a pasty, plastic mass like clay.

We can say in general that shales occur in those regions where the rocks lie flat or nearly so, while slate is found where the rocks have been disturbed, tilted and folded.

PROPERTIES OF SHALE.

Aside from their difference in hardness, clay and shale are practically alike in their properties, so that in this article the word clay could, in every instance, be substituted for shale without destroying the truth.

The properties of shale can be divided into two classes, viz: physical and chemical. The former are more important and have a greater practical bearing than the latter, except where the shale is to be used for making Portland cement.

The most important physical properties are as follows:

Slaking,
Plasticity,
Behavior under heat,
Shrinkage in drying and burning,
Color.

Slaking—If a bed of shale is opened up, it at first appears hard and fresh, but after a while it begins to flake off in large and small pieces which either lie on the surface or fall to the base of the cliff, and these fragments continue to subdivide until the mass is broken down or slaked to clay.

If the shale crops out on a flat surface, we shall find the clay on top, and as we pass downwards a mixture of clay and partially slaked shale fragments is met with, and this mixture in turn grades into the fresh, unslaked or unweathered shale.

Nature will often produce a far more plastic mass by weathering than could be produced by grinding the fresh material. Indeed, these weathered shale beds are often extensively employed in the manufacture of clay products. At East Jordan, for example, the material used for making brick is simply the weathered outcrop of a shale bed, and a similar material is utilized at the Coldwater cement works.

The paving brick works at Saginaw, however, mine the fresh shale and render it plastic by grinding and mixing with water.

Now, it stands to reason that the denser and more firmly cemented the shale mass is the less easily will it slake under the action of the weather, and such a shale would also be harder to grind, that is, it will take longer grinding to break it up thor-

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oughly. We therefore see that the condition of a weathered outcrop is a certain index to the way in which the shale will act in the grinding machines, it being more desirable, of course, to have a material that comminutes readily.

Plasticity—This we can define as the property which shale or clay possesses of forming a plastic mass when mixed with water, thus permitting it to be molded into any desired shape, which it retains when dry. It is hard to realize what an important character this really is, for without it we could do but little with the material.

Shales vary from those in which the plasticity is low to those in which it is very strong. The former are said to be lean, the latter fat or strong.

The very plastic shales, other things being equal, are best adapted for making stoneware and sewer pipe; those of moderate plasticity find their application in the manufacture of paving brick, while the lean ones are used mostly for dry pressed brick and common brick.

If a shale is lean its plasticity can be increased by the admixture of a more plastic one; or, if, on the other hand, it is too fat, it can be tempered by the addition of sand. Sand is a powerful destroyer of plasticity, but it should also be borne in mind that the more sand that is added the greater will be the porosity of the product. Manufacturers of common brick unfortunately have a tendency very often to add too much sand to their clay, because it makes it so much easier to work.

The subject of plasticity will again be referred to under shrinkage.

Behavior Under Heat—When shale is heated up to a temperature of redness or above, depending on the refractory quality of the material, a hardening of the mass takes place, owing to the softening of the particles under the action of the heat, the result of this being that they stick together and make the product when cold as "hard as a rock." It is this property of hardening under fire that makes clay products so resistent and durable.

All shales do not, however, act alike when heated. Some soften very rapidly when burned; others very slowly. Some soften at a very low temperature and are consequently said to be easily fusible; others do not soften until burned to a very high temperature and are called refractory.

Fire clays are refractory and brick clays are usually easily fusible.

When shale is put into a kiln or furnace and burned, the first signs of fusion are a softening of the particles. If the shales be now cooled, it will be a solid mass, and hard enough to cause difficulty in scratching it with a knife. It has been heated to a condition of incipient fusion. If the same piece is heated still higher, the particles soften so much that they are able to adjust themselves better and to pack to a dense, impervious mass, and when cool the individual grains will no longer be recognizable. This is the condition of vitrification, and all stoneware, paving brick and sewer pipe makers try to vitrify their wares

If the piece of shale is once more put into the fire and heated to a higher temperature than before, the clay will finally become so soft as to cause the mass to run or become viscous

This is known as the condition of viscosity. Now, the practical bearing of all this is that, in burning a kiln of ware to vitrification, it is impossible to bring the temperature just up to that point and then stop it; on the contrary, the heat is apt to go a little beyond before it can be stopped. If the shale passes rapidly from the condition of vitrification to viscosity, then there is danger of melting the contents of the kiln in attempting to vitrify them. But if the two points mentioned are some distance apart, then there is not so much danger in slightly overstepping the point of vitrification.

To safely vitrify a clay, the points of vitrification and viscosity should be at least 125° Fahrenheit apart and preferably 200°. *In clays containing a high percentage of lime, they are not over 50° apart, and hence such clays are not adapted to making vitrified wares.*

Shrinkage—All the shales when mixed with water, molded and then set aside to dry shrink a variable amount as the water evaporates. This is known as the air shrinkage, and the more plastic the shale the greater it is, while the leaner or more sandy the shale the less will be the air shrinkage.

A low shrinkage is more desirable for the reason that there is less danger of the ware warping or cracking in drying. When the ware is burned an additional diminution in volume takes place, which is known as the fire shrinkage, and for the same reasons this should be as low as possible. Most shales have a total shrinkage in drying and burning of from 12 to 15 per cent. Knowing the effect of sand on the shrinkage, it is possible to reduce it materially.

Color—Here we have two kinds to deal with, viz: the color of the unburned or green shale, and that of the burned material.

Color of the Unburned Shale—Many persons call a shale associated with coal a fire clay, simply because it is gray or reddish in color, and, while it is true that many fire clays are of this shade, still a large number of fusible ones show the same color, so that this cannot be used as a guide in determining the qualities of shale. Few deposits are wanting in organic matter, such as plant tissue, which is sometimes scattered through the shale in a very finely divided condition, coloring it gray, brown or black. When the shale is burned the organic matter simply burns off. Iron oxide is the second powerful coloring agent, and, depending on the chemical condition in which it exists in the shale, the color of the latter may be red, yellow, brown or even gray. The iron coloration may often be masked through by the presence of much organic matter. The various states of combination in which iron is found in the shale will be mentioned under chemical properties.

Color of Burned Shale—This is most commonly red, owing to the presence of iron oxide in the clay, and provided the combustion of the fire within the kiln is compplete. If, however, there is not enough air admitted to permit complete combustion, then the iron oxide is reduced to a lower condition of oxidation and the color will be bluish black instead of red. The same color will be produced where the clay is burned to viscosity, examples of this being bricks which have been melted in the arches of a kiln.

Shales with only 2 to 3 per cent, iron oxide burn buff, while those with 4 or more per cent. burn red.

A buff or cream color is also produced if the clay contains much carbonate of lime, say three times as much lime as iron, and this is what causes many of the Michigan brick clays to burn a cream color.

Magnesia exerts the same coloring effect on the burned ware as lime, and alkalies tend to turn the iron red into a brown. Silica has no effect on the color in burning.

These, in brief, are the physical properties of shale. There are many other points of practical interest that might be mentioned did space permit, but they will be dwelt upon in my report on the clays of the State, which may perhaps be out next spring.

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THE ORIGIN, PROPERTIES AND USES OF SHALE.

By H. RIES,

Special Agent for the State Geological Survey.

PART II.—CHEMICAL PROPERTIES.

In the previous paper an attempt was made to describe in brief the physical properties of shales. It now remains to describe the chemical ones, or those which are due to the chemical character or composition of the material. An analysis of pure clay would show only three ingredients, viz., silica, alumina, and chemically combined water. Such a clay is however an extreme rarity, so that, in addition to the above, we usually find variable amounts of, ferric oxide, lime, magnesia, and alkalies, and it can be said in general that the purer the clay the lower the percentage of the last mentioned substances. Since we speak of them as impurities, it suggests that some of them may be undesirable constituents of the clay or shale, and such is at times the case, for all of them affect some properties of the shale. Some influence the color, others the shrinkage, while all exert more or less effect on the fusibility of the material, the influences in each case increasing usually with the amount of the impurity which the shale contains. We can perhaps tabulate the above statements by giving in the following lines first the name of the property and after it the substances which affect it:

Fusibility: Silica, ferric oxide, lime, magnesia, alkalies.
Color: Ferric oxide, lime, magnesia, alumina.
Shrinkage: Silica.

On comparing these properties with those mentioned or enumerated in the first paper, it will be seen that there remain some which the chemical composition does not seem to effect, and brings up the question: What can we learn about a clay from its chemical analysis?

As we shall see below, we can learn much, and yet at the same time it is not safe to attach too much importance to this point, for two clays may agree very closely in their chemical composition, and yet be totally unlike physically.

It is commonly the custom to divide the impurities of clay into fluxing and non-fluxing ones, but this is true only in a relative sense, for all of them act as fluxes if present in sufficient quantity, and if the clay be heated to a sufficiently high temperature, but at the same time these latter tend to increase the refractoriness of the clay up to a certain point.

Those impurities, which exert a fluxing action at low or medium temperatures, include the alkalies, ferric oxide, lime and magnesia, and their effectiveness so far as we know is in the order given above.

We could therefore have two clays with the same physical properties and the same total percentage of fusible impurities and yet the one might be more fusible than the other on account of having a larger percentage of the more active fluxes in its composition. For some purposes a low percentage of fluxes is desirable, while for other purposes a higher amount is required.

Alkalies.—These are commonly potash and soda, and are to be found in almost every shale, varying in total quantity from a trace up to nine or ten per cent. They are often present as a constituent of undecomposed feldspar grains, which the shale may contain, or in some cases the potash may come from mica, whose tiny glistening scales are easily discernible when present. Alkalies are usually present in the form of feldspar (which is a complex silicate), and, on account of their fluxing properties, are frequently of an advantage, as they serve in burning to bind the particles together in a dense, hard body, and to permit the ware being burned at a lower temperature. So far as is known the alkalies exert little influence on the color of the burned ware.

Iron Oxide.—Aside from being a flux, iron oxide is also the great natural coloring agent of shales in both their raw and burned conditions. There are many different mineral compounds which may serve as the source of iron oxide in shale, and of these the most common are the silicate minerals, mica and hornblende; the oxides, limonite, hemetite and magnetite; the sulphide, pyrite and marcasite and the carbonate of iron, siderite. No matter what the original composition of the mineral, the decomposition of it usually sets the iron free in the form of the hydrated iron oxide or limonite, which tends to color the clay in various shades of red and yellow. Aside from the mica, the only other mineral which is apt to be present in grains sufficiently large to be recognized by the naked eye, is pyrite, and this occurs in the form of glittering yellow metallic particles, which are often of cubical shape, many of these grains being sometimes cemented together in the form of large masses, which are commonly known as "sulphur balls." The latter would tend to do much damage if allowed to remain in the shale, but owing to their size are easily extracted.

These should not be mistaken with carbonate of iron concretions commonly found in shale banks, and known as clay iron stone, or kidney ore, and sometimes erroneously called sulphur. They do not show any metallic particles unless grains of pyrite happen to be enclosed in them. The shales at Flushing and Quincy, etc., contain many concretions of carbonate of iron.

When a shale is exposed to an oxidizing fire in burning, the iron invariably tends to color the material red, and the

depth of this color increases with the amount of iron present. If, however, the shale is exposed to a reducing action in burning, which is the case when an insufficient quantity of air enters the kiln, then the color instead of being red will be a bluish black. The same color is also produced if even in an oxidizing fire the shale is carried to a condition of viscosity, in which state a dissociation of the iron compound takes place, the ferric oxide being reduced to the ferrous condition.

Both ferric and ferrous oxide exert distinct coloring effects on the raw clays, so that the latter may be yellow, blue, brown, red or grey in color, depending upon the relative amount of ferrous and ferric salts present.

The amount of ferric oxide permissible or desirable in a shale depends upon the use to which it is to be put. Thus kaolins, which are to be utilized for making china, should have under one per cent. if possible, while brick shales or pottery clays, on the other hand, should have four or five per cent. of the same material in order to produce the good red coloration.

The iron coloration may often be bleached out owing to the presence of lime, as will be mentioned further on.

Lime.—There are scarcely any shales which do not contain some lime. The chemical combination in which it is present has much to do with its effect on the behavior of the shales. Thus it may occur as a silicate, when present in some species of feldspar, or again it may be found in the shale as a simple carbonate, represented by the mineral calcite, or as a double carbonate of lime and magnesia when the mineral dolomite is present. Thirdly, it may be found in the shale as a sulphate, namely the mineral gypsum. The latter is often known by its small transparent crystals, whose services have a pearly lustre. The presence of carbonate of lime can be detected by the effervescence produced when a drop of muriatic acid is put on the shale, and dolomite shows itself by acting similarly when hot acid is dropped on the rock.

When the lime is present as a silicate, it is useful as a flux, but in this condition it exerts no coloring action on the shale in burning. Carbonate of lime is extremely common in many shales, which have been derived from limestone areas, as in the State of Michigan, and it is never lacking in those beds of brick clay which are found around the borders of the Lower Peninsula, as at Detroit, Benton Harbor and Forestville. Carbonate of lime if present in the form of lumps or pebbles is very injurious, and shonld be removed by screening or washing, for the reason that in burning it is reduced to quick lime, which if the brick it not vitrified absorbs moisture from the atmosphere, slakes, swells and bursts the product. Finely divided lime, however, if not present in too large quantities may be harmless, and shales containing 15 or 20 per cent. of lime carbonate in this condition can be used for the manufacture of common brick or earthenware, or in fact any products which do not have to be burned to a condition of vitrification.

The effect of lime as a coloring agent is that, if iron oxide is present, the lime unites with it and the silica, and alumina of the shale giving a complex silicate, and coloring the brick buff or cream instead of red. This is especially effective when the ratio of lime to iron is not less than three to one.

Lime like iron and alkalies is also a powerful flux and tends to lower the fusibility of the shale to a marked extent; furthermore it tends to bring the points of incipient fusion and viscosity of the clay together so close that shales which contain a large amount of carbonate of lime can not be burned to a condition of vitrification without danger of fusing.

In addition to this, lime also exerts a powerful influence on the shrinkage of shale, those which are highly calcareous showing a lower shrinkage in burning than those with a low lime percentage.

Magnesia.—This element rarely occurs in either shales or clays in the same amount as lime, and indeed it rarely exceeds two per cent. But curiously enough the shales and the clays at many localities in Michigan often seem to contain as much magnesia as lime.

Magnesia may be derived from the same class of compounds as lime, and, so far as known, the action of it on the clay in burning is exactly the same.

Silica.—Chemical analysis distinguishes two classes of silica, first, that combined with alumina in kaolinite, and, second, sand. The latter includes both quartz and silica present in feldspar or mica.

Free silica or quartz is present in all shales, and varies in amount from a fraction of a percent to about 20 or even 50 per cent. Its most important effects are that it tends to lessen the plasticity, diminish the tensile strength, and also lower the shrinkage of the material, both in drying and in burning. Indeed, if silica is present in a very large amount and grains of large size, it may even cause the shale to expand in burning.

In combination, silica, namely quartz, tends to increase the refractoriness of a clay up to a certain point, namely about 280 degrees F. Beyond that point, however, an increase in the amount of silica tends to increase the fusibility of the clay up to a certain point, after which the refractoriness again rises. This is a question which has a practical bearing, however, only in connection with the highest grades of fire bricks.

Titanium.—While this is widespread in many clays in the form of the mineral Rutile or Ilmenite, at the same time it is present in such small quantities that its effect need not usually be considered. Its action is somewhat similar to that of silica.

Organic matter.—This substance is found in many different shales and usually makes its presences known by the dark gray or black color which it imparts to the material. It generally consists of finely divided pieces of plant tissue, or large pieces of stems and leaves, which have settled in the shale during its deposition.

The color exhibited by clays carrying organic matter is no indication of the color they will have when they are burned, for a clay which is jet black might contain no iron, and consequently would burn with a white color, as the plant tissue passes off at a bright red heat. On the other hand, a clay might contain an appreciable per cent. of iron, whose presence would be masked by the presence of organic matter, and consequently the clay would burn red.

When found in a very finely divided condition, organic matter tends to increase the plasticity of the clay, unless there is a large amount of sand present, and furthermore in the weathering of shales organic matter by its oxidation and consequent evolution of carbonic acid gas helps to break up the material and render it more plastic.

Water in Shales.—All shales contain two kinds of water, viz., hydroscopic water, or moisture and chemically combined water.

Moisture.—Shales contain from 30 to 40 per cent. of moisture, when freshly taken from the bank, and in air drying most of this is expelled. The clay shrinking at the same time. The amount of water that an aired dried clay needs in order to develop an easily workable mass varies from 12 to 20 per cent. in lean ones, and from 25 to 35 in fat ones. The more plastic the shale the greater the quantity of water required.

Combined Water.—It may be said roughly that the amount of combined water in shales is usually about ⅓ of the amount of alumina, although if the clay contains much limonite it would be much greater than this. Combined water is driven off at a low red heat, and the only effect of it is that when this takes place the shale suffers additional loss in volume or shrinks, otherwise combined water has little or no effect, It is a curious fact, however, that while the amount of combined water does not seem to stand in any close relation to the placticity of a clay, nevertheless when once driven off the clay can never again be rendered plastic by the addition of water. The shrinkage that does take place when combined water is driven off will vary from two to twelve per cent.

(To be continued).

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PART III.—USES.

The uses to which shale may be put are groupable under the following heads:

Clay Products, such as brick, terra cotta, sewer pipe, drain tile, paving brick, pottery, etc.
Portland Cement.
Mineral Paint
Road Material.

Clay Products.—This represents by far the most important use to which shale is put at the present time, and for its successful application depends on the two properties mentioned in the previous paper, viz: placticity and hardening when burned. The various chemical and physical properties of shale which have been described in the preceding papers bear chiefly on the use of shale for this purpose.

For the manufacture of all of these clay products the shale must be plastic, but aside from this the characters to be considered for any particular grade of product are not always the same. The necessary qualities may be summed up briefly therefor as follows:

Common Brick.—A sufficient amount of iron oxide to give the brick a good red color is desirable but not absolutely necessary, otherwise we should be excluding the use of calcareous shales, which are sometimes employed, from a matter of necessity rather than choice. There should be enough fluxes in the shale to make it burn to a hard product at a comparatively low temperature, giving a brick whose density should not permit more than 15 per cent. absorption.

Front Brick.—The same characters are called for as in the case of common brick, but the color after burning is of prime importance, it being necessary that the shade, whatever it is, should be uniform. A dense brick is desirable, and the shrinkage should be low enough to prevent warping or cracking in burning. These two points are also influenced by the proper manipulation of the clay. Furthermore, soluble salts must always be guarded against, for they produce a bad discoloration on the surface of the ware. If their presence is known they can be rendered harmless by the addition of barium chloride or barium carbonate to the clay, the chemical reaction which takes place as a result of this addition rendering them insoluble.

Terra Cotta.—The same requirements have to be considered as in the case of front brick, but they must be complied with even more strictly. The necessary plasticity to permit the molding of intricate designs is also of the highest importance.

Paving Brick.—The production of these calls for a shale that will not only keep its shape in burning but also yield a vitrified or impervious product. To produce the latter in large quantities at a time, it is necessary that the points of incipient fusion and viscosity of the shale should be separated by at least 250 degrees Fahr., and preferably 400 degrees. The product should have little or no absorption, and should also withstand abrasion, this being even of more importance than the crushing strength of the brick, although the latter should not be lost sight of, and be at least 7,000 or 8,000 pounds per square inch.

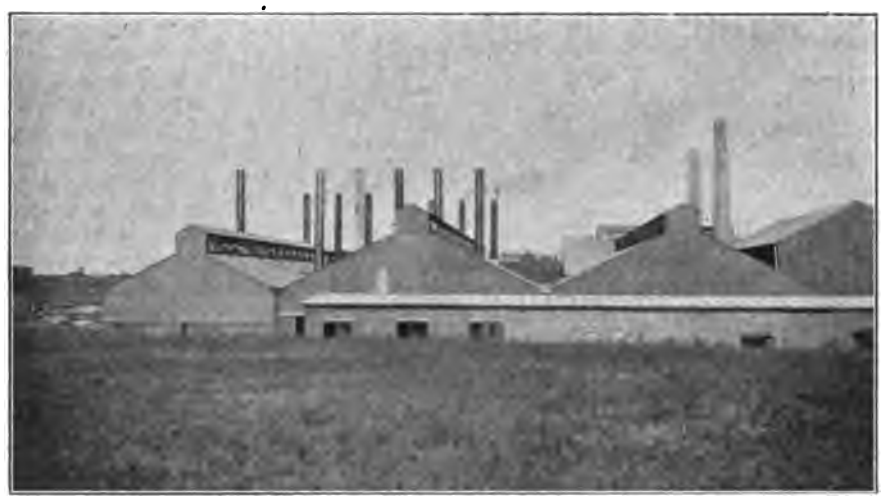
Pottery.—Here plasticity has to be considered, and should be made high in order to permit the turning or molding of the ware. Color is sometimes of importance, and, for stoneware, the shale must burn to a vitrified body. So far as the writer is aware, shale has never been used for the manufacture of whiteware, for the reason that shale being of sedimentary origin it usually has too much iron oxide in its composition to permit its burning to a white body.

Firebrick are very frequently manufactured from shale. The great element to be considered in this case is ability of the ware to withstand high temperatures. This calls for a low percentage of fluxes in the raw material. Fineness of grain always plays an important roll. Coarse-grained shales withstand high temperature best, while fine-grained ones are better adapted to resist the corrosive action of molten materials,

It is frequently found that a mixture of shales often yields much better results than when one alone is used. The bearing of all these points will be discussed in greater detail in the forthcoming report.

Portland Cement—in the manufacture of Portland cement a mixture of shale and marl is usually taken, the two being mixed in such proportions as to give a mixture of the proper chemical composition, the physical properties of the material being of minor importance. The three essential elements of such cement are silica, alumina and lime, the first two of which are supplied by the shale and the latter by the marl or limestone. The best results are ob-

PORTLAND CEMENT WORKS, UNION CITY.



PORTLAND CEMENT WORKS, COLDWATER.

tained from a mixture in which the lime percentage is equal to 2.8 times the silica plus 1.1 times the alumina.

The suitable nature of the Michigan shales for the manufacture of Portland cement has been discussed in an earlier number of this magazine in a paper by Mr. Hale and need not be repeated here.

Mineral Paint.—Shale to be thus employed is usually ground up and mixed with oil. Two characters enter into the consideration of its applicability for this purpose. First, the amount of oil required to mix with a given quantity of shale, and, second, the color of the raw material, which is influenced by the amount of iron oxide and organic matter in the raw material.

Road Material.—In many localities excellent roads are produced by the use of shale, the varieties yielding the best results being those of a somewhat hard and siliceous nature. Shales which are soft and low in silica tend to crumble rather rapidly to dust and produce a greater amount of mud in wet weather.

PART IV.--THE SHALES OF MICHIGAN.

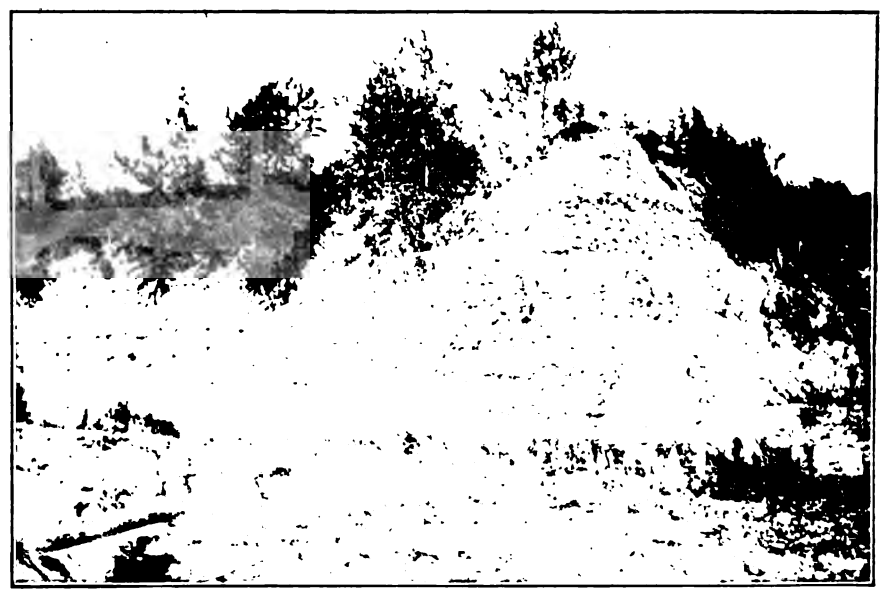
During the past summer the writer had occasion to make an examination of the shale deposits of the State for the State Geologist, and the following will give a brief outline of the work being done.

The object of the work begun at that time and still being carried on is to gather information concerning the extent of the shale deposits of the State, and to determine their value as far as possible for the manufacture of clay products. In order to test their availability, samples were collected from a number of points and these are being subjected to various physical tests and chemical analysis. Among the former may be mentioned the shrinkage of the shale when dried and burned, the color and density when heated to different temperatures, the fusibility, plasticity, tensile strength; also the amount of soluble salts as well as other special points, according to the grade of the shale, all of which information will be of value to the practical clay worker. Analyses are being made of many of the samples, and in many cases it is possible to look upon them as a guide of practical value, and not merely a fact of theoretical interest.

The shale deposits occurring within the State are the following:

1. Coal measure shales, usually interbedded with the coal seams.
2. Michigan series of shales, associated with the gypsum beds.
3. Coldwater shales, outcropping in abundance near Coldwater and White Rock.
4. Marshall shales and sandstones.
5. Hudson River shales, especially developed near Escanaba.

The coal measure shales are, as already mentioned, usually interbedded with coal seams, and most commonly known to the coal miners of the State as "fire-clays." While this application is in many cases erroneous, it may be true in one or two instances, and the term has probably arisen from the fact that in many coal mining regions the coal beds are underlain by a layer of fire-clay or refractory shale, which means the same thing. It is very difficult to give even a most general description of these carboniferous shales, for the reason that they vary so at the different mines, but the same kind is sometimes met with at several mines in succession. The types which are most distinct are perhaps the following: 1, A light gray, sandy, shaly clay, often quite hard, and called fire-clay. It not unfrequently contains plant remains. This material underlies the coal at the shaft of the Standard Mining Company near Saginaw. 2, A black, fine-grained, brittle shale, with dull lustre and sometimes spoken of as cannel coal, owing to its appearance. This shale contains much bituminous matter, and would not serve well for the manufacture of clay products. 3, A dark, grayish black, fine-grained, hard, yet brittle shale, which produces appreciable plasticity when ground up and mixed with water. This is found at several mines near Saginaw and also Bay City, and is quarried at Flushing for the manufacture of paving brick.



SHALE AT WHITE ROCK, NEAR FORESTVILLE

SHALE QUARRY, FLUSHING.

Between these three types are intermediate gradations.

The following analysis shows the composition of the "fire-clay" underlying the coal at the shaft of the Standard Mining Company at Saginaw:

	Per cent.
Silica	55.30
Alumina	14.20
Ferric oxide	3.62
Lime carbonate	.30
Magnesium carbonate	2.61
Alkalies	2.15
Water and org. matter	21.82

This shows a high percentage of organic matter, as the water does not exceed 5.00 probably, judging from the amount of alumina, and consequently there will probably be a considerable shrinkage in burning. The fluxes are also too high for a fire-clay, but the material may be semi-refractory.

These beds of shale at many of the coal mines are four to five feet in thickness, and there is usually an abundant supply of the material. At present it is either left in the mine or else brought to the surface and thrown on the dump, where after a while it begins to slack, first to a scaly mass and then to a powder.

At Grand Ledge the coal measure shales are utilized for the manufacture of tile and sewer pipe, and at Saginaw there is a successful paving brick plant in operation.

The shales of the Michigan series form a belt 10 to 20 miles in width, surrounding the area of carboniferous rocks in the Lower Peninsula. They are, however, best exposed at Grand Rapids, where they form a bed 6 to 10 feet thick overlying the gypsum.

Here the shale is quite soft, and is adapted to the manufacture of red building brick, there being a large plant supported by this supply of material.

The Coldwater shales are perhaps the most extensive in the State, and from the economic standpoint have thus far been the most important, because they are the source of supply of all the Portland cement factories of Michigan. They have been quarried chiefly at Bronson, Union City and Coldwater, but extensive beds also occur at Quincy. At these three points the shale is fine-grained, soft, and weathers rather easily to a clay-like mass. The composition of that used at Bronson is:

	Per cent.
Silica	62.10
Alumina	20.09
Ferric oxide	7.81
Lime	.65
Magnesia	.96
Sulphuric acid	.49
Water and org. matter	7.90
	100.00

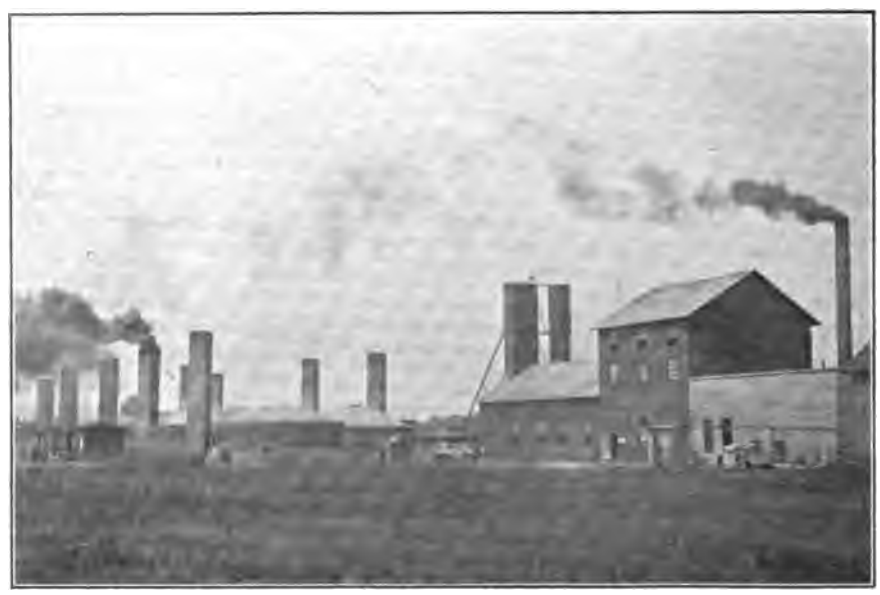
Excellent exposures of this shale occur along the shore of Lake Huron at Forestville, south of White Rock, but they have not thus far been utilized. It is expected that the tests which are now being made on them will demonstrate their usefulness.

Some of the promising shale exposures in the State are those of the Marshall series, outcropping to the southeast and around the village of East Jordan. They weather to a tenacious clay, and burn to a good red color. Like the Coldwater shales, they show evidence of the presence of considerable soluble salt, and this would have to be looked after in the manufacture of certain grades of clay products.

The Hudson River shales, which outcrop abundantly at some points of the Upper Peninsula, especially to the northeast and east of Escanaba, are too highly calcareous and too siliceous to be of any value in the making of clay wares.

In the forthcoming report the characters of these various shales and the tests that have been made on them, as well as the conclusions to be drawn from them, will be discussed in detail,

A word may be said in conclusion concerning the deposits of soft plastic clay which are extensive in many portions of the State. While these clays are in some cases excellently adapted for one use or another, at the same time it will probably prove true that the greatest developments are to be expected from the shales, for the reason that the clays often contain such high percentages of lime carbonate as to restrict their use to the making of common brick and earthenware.



BRICK WORKS, SAGINAW CLAY MANUFACTURING CO. SAGINAW

..THE..
MICHIGAN · MINER.

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THE GEOLOGICAL SURVEY.

Annual Report of Alfred C. Lane, State Geologist, for the Year ending December 31st, 1899.

To the Honorable Board of Geological Survey, Lansing, Michigan.

GENTLEMEN:—Herewith I beg leave to submit my report for 1899, although I have deemed it best to bring the detailed statement only up to July 1st, as owing to the action of the last Legislature the end of the fiscal year was changed from December 31st to June 30th, and we were allowed $4,000 as appropriation for the first half of the year. Owing to the fact that the latter part of the year contains the more summer months and offers most opportunity for field work, and consequently involves extra expenses, and to the fact that the first part of the year was largely devoted to supervising publication, I was not able on such short notice to recommend the expenditure of all the appropriation to the best advantage, and only $3,679.22 was spent and the balance ($320.78) returned to the State Treasury.

EXPENSES JAN. 1ST TO JUNE 30TH, 1899.

	Salaries.*a*	Field.*b*	Office.	
January	$ 363 34	$ 26 20	$ 28 45	$ 417 99
February	386 55	.....	53 17	439 72
March	346 08	52 92	218 37*c*	617 37
April	403 17	10 47	135 17*d*	548 81
May	459 87	2 22	105 72*e*	567 81
June	432 25	10 30	73 94	516 49
Approved since	313 16	116 48	141 39*f*	571 03
	$2,704 42	$218 59	$756 21	$3,679 22

a Including those of temporary assistants if hired for more than a day.
b Traveling expenses, and subsistence while in the field, not including salaries.
c Including $200 for transit.
d Including $100.68 for furniture Lansing office.
e Including $47 50 for barometers and thermometers.
f Including $106 for instruments, etc.

The ratio of traveling expenses has been kept low, but not, I hope, to the detriment of the work.

Hereafter it will be possible for me to give the expenditures for one year from July to July, and the complete series, together with reports of my predecessor, will show the amount expended. Up to December 31st about $3,827.01 only had been expended on the current year. In the preparation of reports on cement by David J. Hale, on clays and shales by H. Ries, and the county reports by Prof. C. A. Davis and Prof. W. H. Sherzer, much work has been done, but no payment is due until the work is complete and ready for publication. You will remember that my predecessor, Dr. L. L. Hubbard, wearied of the obstacles which were placed in the way of publication, resigned his position in January, but that you prevailed upon him to continue in charge, although allowing him to engage in other pursuits, and he remained in charge of the whole survey until April 1st and since then in charge of the Upper Peninsula work.

Publications. The completion of Volume VI was making slow progress and the force of the State Printer had been very largely changed since the printing of the volume began. Your Board and Dr. Hubbard therefore deemed it wise to have some one in Lansing who could look after the matters more directly, and you appointed me to the position of State Geologist, although Dr. Hubbard remains in charge of the Houghton office. The extra work in the printing office at the time of the Legislative session made progress on Volume VI quite slow, and I was not able to get it bound and ready for distribution until August of this year. This volume (Volume VI) pertains to the Copper Country exclusively, and contains a geological map of Isle Royale and some very valuable maps showing the recent developments around Portage Lake. While the proof of this book had been entirely ready before I came to office, and therefore the credit of its preparation belongs entirely to the administration of Dr. L. L. Hubbard, I mention it because the burden of distribution has come entirely upon us. The old mailing list was ten years out of date and adapted for editions of over two thousand were of no use to us. Of the 954 copies turned over to me by the State Printer, 200 have gone to the State Library according to law, 75 were divided between the three authors, 479 were received at the Lansing office, and 200 at the Houghton office.

From the Lansing office have been sold 58 and cash received. There have been distributed (by Governor's order No. 212 to No. 296) to colleges and other libraries in exchange, etc., in accordance with the rules of the Board. 281; and there remain on hand 140. From the Houghton office have been sold 5, distributed 30, and there remain on hand 165. Thus we still have on hand altogether 305. Stubs showing distribution of each volume may be inspected in my office. Applications come steadily in, and are more frequently cash orders of late. It is probable, therefore, that the edition will be exhausted within the year. This is the more natural when we consider that of the more than twice as great edition (2,500 copies) of Volume V issued, more than half (1,453) are already gone. The figures of distribution this year are: In the Lansing office from Superintendent of Public Instruction, 142; sold 11, otherwise distributed 90; on hand 41. In Houghton office at the beginning of the year, 11; distributed (1 sold) 5, on hand 6. Remaining in office of Superintendent of Public Instruction 900. Total on hand 947.

Of the earlier reports we have nothing

to distribute except atlas to Part I of Volume I.

In the meantime my report on "Coal in Lower Michigan" was printed in THE MICHIGAN MINER, as you had arranged, in the numbers from February to September, 1899. Of the 500 copies furnished us by agreement, a number had been distributed in parts or sheets, so that but 370 remained to be bound up together. You authorized the free distribution of this, and but 53 copies remain.

In binding this I took occasion to compile for the rear cover a list of publications, of which we had also some leaflets printed to answer many enquiries.

This publication in the public press of reports in preliminary shape, in accordance with the vote of your Board, has proved very satisfactory, relieving the public treasury of the cost, and securing prompt and wide dissemination of our reports.

Prof. Ries has been printing a similar series on the clay and shale resources of the State in THE MICHIGAN MINER, and shorter notes on the marl resources and the work of D. J. Hale, and on the glass sand and the work of W. H. Sherzer on Monroe County, have appeared in the daily press.

Prof. Davis has published some account of work in Tuscola County in the ***Botanical Gazette***, and I have published studies on the "Water Supply and the Mineral Waters of Lower Michigan," in Water Supply Papers No. 30 and No. 31 of the U. S. Geological Survey. I have also in response from teachers prepared some articles on the, 'Making of Michigan" for the ***Moderator***. We are constantly in receipt of enquiries for reports of the Commissioner of Mineral Statistics. Since these were at one time distributed by your Board, and as there have been five different incumbents within the last ten years, all living in different parts of the State, it is no wonder that enquiries come to us, and that even the State Librarian finds it difficult to secure a complete file.

In order to see that the college and local libraries are supplied throughout the State with complete files, it might be well to have a part or the whole of each edition of the Geological Survey, Mineral Statistics, and similar reports distributed through one central bureau. Of back reports we have of the 1884 report 15, and of the 1891 report 121, which I am giving to applicants.

Future Publication. The Legislature granted $4,000 for future publication, and the engraving and lithographing of maps and other illustrations for county reports on Monroe, Huron and Sanilac Counties are well advanced. We are allowed to print 1,500 copies. Judging from the experience of the past, this will be not more than barely sufficient if you allow me as you have to print 500 copies of each county report separately to supply local demand, leaving 1,000 to be bound together as Volume VII of our reports for those who wish to keep sets of the same.

Besides enquiries for the reports of the Commissioner of Mineral Statistics, we have a great many miscellaneous enquiries regarding the resources of the State, many of which would be most appropriately answered by him, of which we keep no exact track, for our stenographers are too busy, but our bill for stamped envelopes indicates for them over 1,500 letters written.

Relation to Other Bureaus. The mention of the Commissioner of Mineral Statistics reminds me to refer to our relations with other bureaus. The wording of the acts which refer to the State Geological Survey and the Commissioner of Mineral Statistics is such that there might very easily be a wasteful duplication of work and possible friction. As a matter of fact, however, there has been no such difficulty for years past, the collection of statistical information being left entirely to his bureau. It might seem natural, and, indeed, I have been asked, why we did not pay more attention to such matters, which are in most States placed in the hands of the Geological Survey; but it must be remembered that there are three other bureaus—the Commissioner of Mineral Statistics, the Commissioner of Labor, and the U. S. Geological Survey, which are engaged in gathering statistics relative to the mineral and kindred industries of the State, and it seems to me that it would be a waste of time for a fourth agency to do the same work, especially when we have absolutely no authority to compel returns and when the various people addressed might fairly complain that their time was occupied in filling out blanks for more than was right. Along our peculiar lines, however, we have, with very few exceptions, received every courtesy, and I think all the more because such is entirely voluntary on the part of the various mines and owners.

The Michigan College of Mines has furnished tests of cement by Prof. Hood, and other analyses by Dr. Koenig.

The U. S. Geological Survey have not only assisted in the gathering of water supply data, as already mentioned, but have promised to determine our coal measure fossils. They purpose to study the glacial geology of the State in a general way, which will facilitate our detailed investigations, and are expecting our assistance.

We have also received for Mr. Hale and Prof. Ries courtesies in the way of transportation from the Grand Rapids & Indiana; Ann Arbor; Saginaw, Tuscola & Huron; Manistee & Northeastern; the Soo Line, etc,, which have materially aided them in their work.

The removal of my residence from Houghton to Lansing has brought me into more intimate relations with the Agricultural College, and I have gratefully to acknowledge many courtesies from the faculty, especially in chemistry, of that institution, and I trust have been able to render them some assistance in return, having visited the new experiment station at Chatham at the request of Prof. Smith and agreed to speak at Pontiac in January for the Farmers' Institute.

C. F. Schneider, of the Weather Bureau, has compared our instruments with his, and I have furnished Prof. I. C. Russell with jars and other material for keeping record of the new well put down by the University at Ann Arbor. I have also furnished Mr. G. B. Willcox, of the Mechanical Department, with standard samples of coal tested.

Field Work in Lower Michigan. During the summer Prof. C. A. Davis finished work in Tuscola County, and his report is appended. I myself visited the county a short time, but was employed most of the time in Saginaw County, and was assisted by Mr. J. G. Whitten and Mr. W. F. Cooper, and in topography by Mr. Charles Holmes. Prof. W. H. Sherzer has spent a short time reviewing the work on Monroe County, but has spent most of his time preparing a report on the same. Mr. D. J. Hale has been employed as a special agent in writing up the cement materials. I have been fortunate enough to get Prof. H. Ries, of Cornell University, who has for some years been employed as expert by the United States, New York, North Carolina and other States, to look over and examine the clay and shale resources of the State. In the way of special tests, a series of analyses and heat determinations with a bomb calorimeter have been made by Henry J. Williams from samples collected by us with care, and a series of tests of clays, marls and waters, and some miscellaneous analyses by A. W. Clark, of the Agricultural College, mainly for D. J. Hale. The results of the work may be briefly summarized.

In Saginaw County, the approximate mapping of a deep channel which passes west of Saginaw toward Alma and cuts out the coal; the recognition of three important coal seams, the lower non-coking but low in sulphur and ash, of heating quality equal to the Hocking Valley, and two coals above, often so close together as to be workable as ores, which are coking coal but higher in sulphur, phosphorous and ash; the rec-

ognition of nodules and bands of iron carbonates and occasionally as zinc widespread in the coal measures, so that very likely they are somewhere present in economically valuable quantities.

In regard to cement material, the wide and abundant occurrence of marl material has been demonstrated. The rarer material is a suitable clay or shale to mix with it. None of the surface or glacial clays have proved very suitable, and shale or clay derived by decomposition therefrom seem to be the best adapted. This, however, exists in large quantities in the Coldwater shales, which occur at both ends of the State and probably also in other horizons. Dr. Ries thinks there is a bright prospect for clay and shale industries in the northern part of the Lower Peninsula.

The coal tests by H. J. Williams have shown clearly the chemical characters of the various seams, and that previously published analyses had not given a fair idea of the range of coal. They enable, as it seems to me, the heating power to be computed from a proximate analysis quite closely, which will save considerable expense to enquirers hereafter. They are the first accurate tests known to me, and were made with the apparatus after which that of John Hopkins University was modeled.

Prof. Davis' work is recorded in his sub-report.

Beside the work mentioned, there has been a great deal of answering queries and of advice given as to coal and other explorations, in this year of active exploration, which has taken not a little time.

To keep better informed as to these, I have had at my own expense of $3.00 a month subscribed to a press clipping bureau which keeps me fairly well informed of any wells sunk or other explorations. Among much inaccurate information there is much of value, and, though I propose to continue the service myself for a time, I feel that it would be wise for the Board to continue it. It will in a few years be an invaluable record of explorations, and nothing is surer than that explorations frequently fruitlessly repeated because accurate and authentic records of earlier ones are not kept, and thus the report grows that some mysterious money power, usually the Standard Oil Company, bought off the explorers just as something rich was struck.

We have continued to help in keeping an assistant at the deep well in Bay City, studying the fine geological columns which are thus exposed.

From Nebish Island and Cheboygan on the north to Ann Arbor and Riga on the south there has been unusnal activity the past year in boring deep wells, and considerable addition will be made to our knowledge of what may be expected from such borings.

PROPOSALS FOR 1900.

Publication. In the coming year I trust that the reports for Huron, Monroe and Sanilac Counties will be out, and possibly those of Tuscola and Saginaw Counties. If we had not so much back work to make up it would be possible to get out Saginaw County this winter, but it looks at present as if it would be hardly possible in any case to get it out before next spring, and probably the preparation of the report will bring out matters which may reqnire a little revision in the early part of next season. It would be natural to push the work on into Bay County, where there are very important coal developments, and into Gratiot County, where Prof. Davis has already accumulated facts. I plan to push the work up toward the north of the State, where there is a demand for it and where economic results are to be expected. There are as good prospects for oil or gas southeast of Alpena as around Port Huron. The same region seems promising good for cement, pottery and other clay industries. There is also a good pemand for limestone at present, and the region from Alpena to Cheboygan offers every prospect for geological work, which would be valuable both scientifically and economically, but which cannot be undertaken with any satisfaction until the work of collection and of previous observers, Drs. Winchell and Rominger, are accessible as a base for our work. It is absolutely foolish to go over the State and do what has already been done. It must be remembered that with the completion of the Isle Royale report in Volume VII the State Geological Survey has covered the State in a general way, and the kind of work which is now necessary and desirable is of a more minute character, leading to more specific and practical results. There are a great many parts of the State in which such work would be profitable, and it seems therefore highly advisable not to push it in any one part until special conditions are favorable—that is to say, until a good topographic base has been provided, if there is any prospect of such a one being made, and until the work of previous workers is accessible to the public, so that we may not have to do the work over again, but go on the greater accuracy and detail. Unfortunately Dr. Winchell's collection and drawings are not accessible to the public, and the same thing is nearly true of the vast amount of material which has been collected by Dr. Rominger, although he still lives to give the information as a Nester to younger men. Both of these collections, however, should be put in some public museum, where the State Geological Survey could have the use of them in its work. I am very glad that the Kent Scientific Institute collections are to be placed in charge of the Normal College. I have rendered some assistance to Miss E. J. Cole and Mr. J. F. Nellist in studies of Kent County, and our work from Saginaw and Gratiot Counties might naturally spread to Kent, where the problem of water supply, etc., invite geological investigation. In the same way it would be natural to work from Saginaw south toward Ingham and Livingston Counties, continuing our studies of the coal measures.

Again, if our funds were not far too limited, from Sanilac County it would be wise to work south into St. Clair County, and study the oil and gas development around Port Huron. This latter might well be combined with a special report on the prospects for oil and gas in the State. Which one of the various avenues inviting work shall be taken up will depend on the men available therefor.

There are two classes of work now being pushed in all State surveys. One is thorough examination of small areas (counties), the other is the examination of special objects. Our county reports belong to the first class and are distinctly implied and authorized by the law, which provides that the State Geologists shall file all county reports with the Land Commissioner. The other class of reports are equally important and are also called for by law. Such are the reports on cement material by D. J. Hale, that of Dr. Ries on clays and shales, and of myself on coal. In all probability the expense of the preliminary publication of special subject reports can be largely saved the State, if your honorable Board so chooses, by their publication through private channels. They will not receive the same distribution as though they were published by the State itself. Yet it is a question with me, whether a report printed, for example, by THE MICHIGAN MINER, or in a daily paper, does not get more prompt and intelligent attention than one issued as a State report. I am very well satisfied with the results of printing the coal report in THE MICHIGAN MINER, though I think that a revised edition containing later data should be issued by the State, uniform with other reports, for distribution to public libraries and other places where sets of our reports are desirable.

Besides the reports already in preparation, others on the prospects for oil and gas in the State, on the sources of high-grade limestone, and on the distribution of gypsum (plaster), would, as I know from enquiries, meet a demand. The U. S. Geological Survey are plan-

ning for the next two years a reconnaisance of the glacial or surface geology of the State, in which we have promised to co-operate. When that work is done there will be a large amount of material toward a special report on the soils.

Upper Peninsula. Dr. Hubbard has kindly consented to take charge of the Houghton office gratuitously, and so long as he will do this the location of the State Geologist at Lansing has many advantages, and he has promised to prepare for us, at his earliest leisure, a report on the correlation of the copper-bearing lodes of Houghton and Keweenaw Counties. It has been fonnd that the land survey is so defective that the correlation of outcrops, which are platted with reference to sections supposed to be square, is liable to lead to very erroneous conclusions as to the structure and the direction of the copper-bearing lodes, and, therefore, it has been necessary to prepare an accurate transit line running along the copper-bearing range and get the true shape of the sections immediately adjacent. This has been done from Houghton to Rockland and will be pushed in the coming season. It is slow work and expensive.

There is a very tempting work open to the survey in the Iron Country, which has been for a number of years studied by the U. S. Survey. While they were there it was understood that we should not be there because it is obviously a waste of Government funds for two organizations to be studying the same place at the same time. They are now through with their field work, and it may soon be advisable for us to gather up the ever-accumulating mass of new information. This part of the State is, however, owned by a few large corporations, which can and do conduct private geological surveys of their own on a scale of expense and thoroughness far beyond what we can afford. All we can give is a certain modest amount of co-operation in return for the records, which in the last years of busy activity have been accumulating faster than we can master them. There are over thirty companies now exploring in the copper region. More and more of the mining men of the Upper Peninsula are appreciating the Geological Survey and are furnishing to it drill cores and records which are fast filling up our modest building. The present condition of the gold industry in Upper Michigan also invites attention. There seems to be no reason, geologicallv, why gold mines should not be successful, as, for instance, in Minnesota. The opportunities for the usefulness of the survey are far more numerous than its funds will permit it to seize.

Value of the Survey. A few instances have come to my attention this year illustrating the value of the survey which may be worth stating here. The preliminary newspaper publication of Prof. Sherzer's researches on the glass sands of Monroe County brought to my office an inquiry from the Libbey Glass Company of Toledo, Ohio, which resulted in an immediate large order. And we have been able to guide other enquirers for the same material. The work upon the variation of the grain of rocks has enabled Dr. Hubbard to order discontinued a shaft when he found that it was sinking into a thick bed of trap, whereas otherwise he might not have known whether he was near foot or hanging. On the coal report I will quote only a short paragraph from a letter received: "The report, I think, of the greatest importance to the State, and the fact that it has appeared just when it is most needed makes it doubly appreciated by persons like myself, who can make immediate and practical use ot the information it contains."

But the crowning illustration of the value of the reports is given by Dr. Hubbard's work. Dr. Hubbard's work on the correlation of the copper-bearing rocks is published in Vol. VI. He has since been employed as agent of the Copper Range Company. The subscription value of this corporation was $2,000,000, and even at present market prices after the panic it is selling for $3,000,000 when the value of other properties has been nearly wiped out. The difference must at least in part be ascribed to the fact that Dr. Hubbard has found and opened upon the Baltic lode in eleven different places, making an exhibit which in the time occupied is almost unequaled. If we consider the rise in the value of the stock and its holding the same to be due to Dr. Hubbard's success, and I think there is no doubt that it is so due in large part, then we can easily see that the taxes on this increase in value would alone almost suffice to pay the entire appropriation for the Geological Survey indefinitely. While it is pleasanter and more attractive to point to value actually given to the State by the publications of the survey, it is probable quite as useful in saving money, when, for instance, explorations for coal at Sand Beach and Fruitport are not undertaken because the maps of the survey show that there is no coal there, or when a well 200 feet deep about to be abandoned as too salty is saved for domestic use by publication of geological information by Prof. Davis, there is as much real utility as if the money which would otherwise be spent in fruitless explorations or in new wells was actually gained.

As there has been no transfer of equipment in the Houghton office to my charge, and the books received in exchange have come in part to my office and in part to the other, I omit this year's statements of additions to the library and equipment which have sometimes been made. There has been considerable addition in both departments. The samples of coal and clay taken for testing were large ones averaging about 25 pounds and after careful quartering the amount needed for tests used. The balance has been returned to us and is at the disposal of college laboratories who wish for check material.

Prof. Davis' report on his work in Tuscola County I append. I may add that his work shows in the "prairies" of the county the flora characteristic of the fruit belt of Southwestern Michigan, and leads to the well-grounded expectation according to the law that crops which can be well produced far from chief centers of production bring best prices that the fruit industry will be profitable there.

Respectfully submitted,

ALFRED C. LANE,

State Geologist.

DR. ALFRED C. LANE,

State Geologist, Lansing, Michigan.

SIR:—In accordance with your verbal and written instruction, the first two weeks of July were spent working out the results of part of my field work in Tuscola County during 1898. On July 14th I began work in the field, taking up the field work where it was broken off in 1898. My first work was to complete the survey of the region about Mayville, especially the morainal deposits there and those lying to the north and east of the village, in Clayton and Koylton Townships. In this region the moraine is very high, nearly 1,000 feet above tide level at Mayville, and also presents many features of scientific interest. The thing which most especially attracted my notice was the fact that all the formations attributed commonly to the action of water from the melting front of the ice sheet are to be found on the north side of the main morainal deposit. These formations are such as the hillocks of unsorted gravel, known as kames, sandy knolls and the numerous minor topographic forms which were developed beyond the line of main deposit in front of the ice sheet, one exceedingly abundant and well marked and present in highly interesting variety, all along the north side of the moraine in the towns mentioned. In Dayton Township it is also evident from the way in which these formations lie with regard to the main moraine that there were several minor projections of the ice northward a short distance, while between these strong streams of water flowed northward into the bay, which is now the Cass River. The larger part of these old valleys are now occupied by swamps and marshes, which are only partly drained by small sluggish streams flowing through them. The most remarkable kame deposit noted is a great mass, having the typical rounded outlines of the true kame, which marks the limit of the northward extension of this class of deposits in Dayton Township. The hill is on section 5 of Dayton, and from its top the whole panorama of the Cass River Valley is visible, as from no other point which was visited by the writer. Due north of this kame there was no marked and unaltered glacial deposits until the lesser uroranial ridge in Ellington Township was reached, on the other side of the Cass. In Koylton Township several well marked eskers were traced, the details of which are of interest, but which cannot be incorporated in this brief report. The region on the south side of the moraine as far as it was examined (that part lying in Tuscola County) sloped with a gradual and smooth descent which had few interesting features into a comparatively flat plain. About several of the small lakes in this section the presence of marl was sited, but no systematic attempt to locate beds of this material was made, but from the swamp and spongy nature of the soil in many parts of the township lying to the north of the ridge it is probable that considerable beds exist in favorable places. After the work in the region about Mayville was completed, the townships of Kingston and Novesta were gone over, and, as these were all that had not previously been explored. I by your direction began the preparation of the final report on the natural resources of Tuscola County, which work occupied me until the first of October and has been continued since as time and opportunity offered.

Respectfully submitted,

CHARLES A. DAVIS,

Alma College, ***Field Agent.***

Alma, Michigan,

December 18, 1899.

THE MICHIGAN MINER.

A Monthly Journal devoted to the Mineral Resources of the Peninsular State and Mining in General.

THIRD YEAR. Vol. 3—No. 1. | Saginaw, Mich., December 1, 1900. | $1 Per Year. In Advance.

DR. L. L. HUBBARD.

Sketch of One of Michigan's Noted State Geologists, from the Pen of Dr. Alfred C. Lane, the Present State Geologist.

My predecessor, Dr. Lucius Lee Hubbard, was born in a year of good omen to geologists and miners, '49, in the city of Cincinnati, Ohio. He spent his boyhood days in that State, but went East to be fitted for college and was graduated from Harvard in 1872. The next two or three years were spent in study abroad at the University of Bonn and the Boston School of Law, where he received his degree of LL.B. in May, 1875. At that time he had thought of taking up diplomacy as a profession, but then, as now, the United States differed from most other nations in requiring no special training for her foreign service, and not offering any life career in diplomacy. The next few years were spent in business and legal practice around Boston, but the keen eye and discriminating mind which had made him a successful philatelist, and his love for outdoor life, drew him into scientific pursuits. He had for years spent his vacations in the woods of Maine, and his two books, "Summer Vacations at Moosehead Lake and Vicinity," and "Woods and Lakes of Maine," the latter with an excellent map, are still standard authorities for those exploring around Mt. Ktaadn. In 1883 Science had finally claimed him for her own. In 1886 he took the degrees of A.M. and Ph.D. from the University of Bonn, where he worked with Von Laseaulx, and in November continued his studies at Heidelberg under Prof. Rosenbusch. It was there that I first met him. One product of his studies in Germany was a paper on certain features of the volcanic rocks of Germany, entitled "Beitraege zur Kentnisse der Nosean fuehrenden Auswuerflinge des Laacher Sees."

DR. L. L. HUBBARD.

In 1891 he entered the service of the State Geological Survey of Michigan, which was then directed by Dr. M. E. Wadsworth, who was at the head both of the survey and of the Mining School at Houghton, Mich. Dr. Hubbard also gave instruction in mineralogy and lithology. A list of the minerals of Michigan compiled by him will be found in the report of the Michigan Geological Survey for 1891-92, page 174.

In 1893 the Board of Geological Survey determined to make the connection of the State Survey with the Mining School less close, and Dr. Hubbard was appointed State Geologist, while Dr. Wadsworth remained at the head of the Mining School. The first fruit of the new departure was seen in Volume V of our reports, which was issued in 1895, and the preparation for the publishing of Volume VI was promptly undertaken. When the auditing of the bills for it, however, came into the hands of a new Board of Auditors, unexpected difficulties arose which caused Dr. Hubbard unprofitable trips to Lansing and delayed the publication of the same. The State Printers also

have been inclined to postpone work on such large reports to the summer months, when there is not so much legislative or other pressing work, but on the other hand the summer is precisely the time when the geologist is most away from his office and is likely to be most busy; consequently the issue of Volume VI was postponed beyond all expectation. At length, wearied by repeated obstacles in his way, and especially by the vote of the Board of Auditors that they would allow no further printing until action had been taken by the Legislature, Dr. Hubbard resigned, January, 1899. Before his resignation took effect, however, he was appointed manager of the Copper Range Company. Their judgment was amply justified by the discovery of the Baltic lode, which was supposed to exist on their property, by Dr. Hubbard personally, and in a very short time, and at vastly less expense than is usually incurred by preliminary explorations, he had the lode opened upon in eleven places, seven of which were rich, thus assuring the future of the Champion mine (as it is to be called) beyond question.

Dr. Hubbard's account of theories regarding the origin of salt, gypsum, and petroleum, in Volume V, is frequently cited. In Volume VI his explanation and description of the intrusive felsites of Keweenaw Point is of great interest to the geologist and a distinct correction and improvement on previous authors in the same field, while his last chapter on the recent work around Portage Lake is of great practical value.

Beside the issue of Volumes V and VI of our reports, some other papers by Dr. Hubbard on Michigan subjects are as follows:

"On Powellite from a New Locality," Am. Jour. of Science, XLVI, Nov., 1893.

"Two New Geological Cross-sections of Keweenaw Point."

"The Relation of the Vein at the Central Mine, Keweenaw Point, to the Kearsarge Conglomerates." Proceedings Lake Superior Mining Institute, 1895.

Dr. Hubbard is a proficient rifle shot and an imperturbable and formidable whist player, having been President of the Upper Peninsula Whist League. He is also an active Churchman, and was elected a delegate to the last general convention.

On September 29, 1875, he was married to Francis J. Lambard. Of the three living children, the eldest daughter is married to Horatio Stuart Goodell.

Although he is not drawing any salary from the State, he still continues to take a helpful interest in the work of the Geological Survey, and I hope before long to have a report from him upon the Correlation of the Copper-bearing Lodes, which no man living is better qualified to give.

ALFRED C. LANE.

PUBLICATIONS

DOUGLAS HOUGHTON, State Geologist.

Reports from 1838-1846 were published with Legislative documents as follows: S. D. means Senate document; H. D., House document; J. D., joint document. State Geologist is abbreviated S. G., and State Geological Survey, S. G. S.

1838. Report of a select committee of the Board of Regents of the University on the collection of the S. G.
H. D. Vol. I, p. 1-2; S. D. No. 1, p. 1. H. D. No. 35 is duplicate of No. 1.
Statement of the expenditures on account of the S. G. S. for the year 1837.
H. D. No. 8, pp. 115-118; S. D. No. 21 (First annual account of the S. G.), pp. 315-318.
Report of the S. G. (first annual).
H. D. No. 24, pp. 276-317; S. D. No. 16; separately, No. 14, pp. 1-39.
Communication from the S. G.
H. D. No. 46, pp. 547-460.

1839. Report of the S. G. in relation to the improvement of State Salt Springs.
H. D. No. 2, pp. 29-45; S. D. No. 2, pp. 1-8.
Report of the committee on the S. G.'s report in relation to the improvement of the State Salt Spring.
H. D. No. 4, pp. 122.
Report of the S. G. in relation to the iron ore, etc., on the school section in town five south, range seven west, in Branch county.
H. D. No. 21, pp. 342-344.
Second annual report of the State Geologist.
H. D. No. 22, pp. 380-397; S. D. No. 12, pp. 264-291; also separately H. R. No. 23, and S. R. sometimes misprinted No. 13 and No. 23, pp. 39 and appendix of subreports 122 pp.
Report of the Committee of the Senate on Manufactures, to whom was referred the communication of the S. G. relative to salt springs and the saltnes of the State.
S. D. No. 3, pp. 85-86 (parallel to H. D. No. 4).
Communication from the S. G. relative to the G. S.
S. D. No. 25, pp. 463-466; J. D. No. 3, App.

1840. Report of S. G. relative to the improvement of the salt springs.
H. D. No. 2, Vol. I, pp. 18-23; S. D. No. 8, Vol. II, pp. 153-158.
Annual report of the State Geologist (third map of Wayne county).
H. D. No. 27, Vol. II, pp. 206-293; S. D. No. 7, Vol. 2, pp. 66-153; separately, H. R. No. 8, pp. 1-124.
Report of the select committee to whom was referred the several reports of the S. G.
H. D. No. 46, Vol. II, pp. 455-461.
Report of the majority of the Committee of Finance on the communication and accounts of the S. G. for 1839.
Report of the minority of the Committee on Finance on the same subject.
Report of the select committee on S. G.'s report and accounts relative to improvement of Salt Springs, etc.
S. G.'s account for the year 1839, the same being the subject matter of the three preceding reports.
S. D. No. 15, 16, 17, 18, pp. 209-224.

1841. Special message concerning state salt springs.
H. S. and J. D. No. 5, pp. 235-254.
Annual report of the S. G. (fourth).
H. S. and J. D. No. 11, pp. 472-607; separately H. D. No. 27, pp. 1-184; S. D. No. 16, pp. 1-184.
Report of the S. G. relative to county state maps.
H. D. No. 35, pp. 94-98.

1842. Report of the S. G. relative to the State Salt Springs.
H. D. No. 2, pp. 15-21; S. D. No. 1, pp. 1-9.
Report of the select committee in relation to the report of the S. G.
H. D. No. 19, pp. 77-79.
Annual report of the S. G. (fifth).
H. D. No. 14, p. 6; J. D. No. 9, pp. 436-441.

1843. Annual report of S. G. (sixth).
H. D., S. D., and J. D. No. 8, pp. 298-402.
Report of the S. G. relative to the State Salt Springs.
S. D. No. 9, pp. 402-408.

1841. Annual report of the S. G. (seventh).
S. D. No. 11 (three pages).
Maps of Washtenaw, Calhoun, Jackson and Lenawee counties were published separately.

1846. Report from Geological Department by S. W. Higgins, principal assistant.
J. D. No. 12, 27 pp.
Report of the joint committee relative to the Geological Survey.
J. D. No. 15, 8 pages.
D. Houghton undertook an arrangement with the Linear Survey of the U. S. Land Office by which a certain amount of geological work was done, which was never published by the State, the results of which appear largely in the township plats of the Land Office, and in the report of C. T. Jackson, 1849, U. S. S. Ex. Doc. No. 1, pp. 371-425, H. Ex. Doc. No. 5, Vol. 3, Part 3, including sub-reports of W. A. Burt and Bela Hubbard on the geology of the subdivisions of the Linear Survey, First Session 31st Congress, and of Foster & Whitney, U. S. Geologists, Part I, H. Ex. D. No. 69, pp. 1-224 and 12 Plates, First Session 31st Congress; S. Ex. D. No. 2, Vol. 2, p. 147, Second Session 31st Congress; Part II S. Ex. D. No. 4, Vol. 2, p. 3, Special Session 33d Congress.
We may add as containing work done under the S. G. S.:
Reports on the Mineral Region of Lake Superior, with a correct map of the same and a chart of Lake Superior (first title page). Reports of Wm. A. Burt and Bela Hubbard, Esqs., on the geography, topography and geology of the U. S. Surveys of the Mineral Region of the South Shore of Lake Superior, for 1845; By J. Houghton, Jr., and T. W. Bristol, Detroit, 1846 (second title page).
A second edition was published the same year in Buffalo by J. Houghton, Jr., the title being "The Mineral Region of Lake Superior."
The "Memoir of Douglas Houghton," by Alva Bradish, Detroit, 1889, which reprints the early reports almost in full.

A. WINCHELL, State Geologist.

1861. First biennial report of the progress of the G. S. of M. Embracing observations on the Geology, Zoology and Botany of the Lower Peninsula, Made to the Governor Dec. 31, 1860.
The Walling Tackabury State Atlas contains a paper with geological and topographic maps by A. Winchell, reprinted separately under the title "Michigan."

1869. Report of the Joint Committees on Geological Survey, made to the Legislature of Michigan, Lansing, W. S. George & Co., Printer to the State, pp. 1-15.

1871. Report of the progress of the S. G. S. of M., pamphlet, pp. 1-64.

1873. Vol. 1. Upper Peninsula, 1869-1873. Accompanied by an Atlas of maps. Edition 2,000.
Part I. Iron Bearing Rocks (Economic), T. B. Brooks. Of this an extra edition of 500 with thirteen accompanying atlas plates (1 to 13, No. 2 is misnumbered 11) was issued.
Part II. Copper Bearing Rocks, Raphael Pumpelly (Plates 14, 14a, 15-23 of the atlas accompanying. Chapters IV, VII, VIII are by A. R. Marvine).
Part III. Palæozoic Rocks, Dr. C. Rominger. (Plate 24 of the atlas accompanies. There was an extra edition of 500 dated 1872, without map or index, differing slightly in title page, introduction and paging).
Vol. II. Upper Peninsula. 1869-1873, appendices to Part I, Vol. I. A Lithology by A. A. Julien, B. Lithology by T. B. Brooks and A. A. Julien, C. Lithology by Charles E. Wright, D. Ore deposits, E. Lithology (Notes by D. Houghton), F. Iron ore dock (by Jacob Houghton and Chas. H. Palmer, with Plate 20), G. Census statistics (1870), H. Magnetic Analyses (by F. B. Jenney), I. Mining laws (by C. D. Lawton), J. Metallurgical qualities by H. B. Tuttle, K. Contortions of Laminæ (by T. B. Brooks).

C. ROMINGER, State Geologist.

1876. Vol. III. Lower Peninsula. 1873-1876, accompanied by a geological map. Edition 2,000.
Part I. Geology of the Lower Peninsula, by C. Rominger.
Appendix A. Observations on the Ontonagon Silver Mining District and the State Quarries of Huron Bay, by C. Rominger. B. Report on the Salt Manufacture of Michigan, by S. S. Garrigues, Ph. D., State Salt Inspector.
Part II. Paleontology. Fossil corals, by C. Rominger (with 55 plates).

1881. Vol. IV. Upper Peninsula. 1878-1880, accompanied by a Geological map. (Edition 2,000.) Part I. Marquette Iron Region. Part II. Menominee Iron Region, by C. Rominger.
See also Vol. V, Part I.
The geological work beginning in Vol. I was continued by Brooks, Pumpelly and Wright in the reports of the Wisconsin Geological Survey. Out of print.

C. E. WRIGHT AND M. E. WADSWORTH, State Geologists.

See Vol. II and Vol. V, also the reports of the Commissioners of Mineral Statistics and the following entry:

1887. Report of the State Board of Geological Survey for the years 1891 and 1892, to which are appended exhibits Setting Forth the Expenses of the Survey from its Inception to November, 1892, Exclusive of the Cost of Publication. Also the Reports of Dr. Carl Rominger for the years 1881-2; of Mr. Charles E. Wright for the years 1885-8; of Dr. M. E. Wadsworth for the years 1889, 1890, 1891, 1892, made to the State Board of Geological Survey for the years named; also a Provisional Report by Dr. M. E. Wadsworth, State Geologist, upon the Geology of the Iron, Gold and Copper Districts of Michigan.

L. L. HUBBARD, State Geologist.

1895. Vol. V. Upper Peninsula, 1881-1884; Lower Peninsula, 1885-1893. (Edition 2,500.)
Prefatory Historical Note by L. L. Hubbard.
Part I. Geological Report on the Upper Peninsula of Michigan, exhibiting the progress of work from 1881-1884. Iron and Copper Regions, by C. Rominger, accompanied by a map and two geological cross-sections.
Part II. The geology of Lower Michigan, with reference to deep borings. Edited from notes of C. E. Wright, late State Geologist, by Alfred C. Lane, Assistant State Geologist, with an introduction on the origin of salt, gypsum and petroleum, by Lucius L. Hubbard, and accompanied by seventy-three plates and a map.

1899. Extracts from the annual reports of the State Geologist of Michigan, Lucius L. Hubbard, for the years 1897-1898. (By an error in Lansing this report really contains only the report for 1898. Edition 500.)
Vol. VI. Upper Peninsula, 1893-1897 (edition 954, and 200 of each part privately printed).
Part I. Geological report on Isle Royale, Michigan, by Alfred C. Lane, Assistant State Geologist. Accompanied by 16 plates and 29 figures, including map in cover.
Part II. Keweenaw Point, with particular reference to the felsites and their associated rocks, by Lucius L. Hubbard, State Geologist. Accompanied by 10 plates and 11 figures.
Part II. Appendix. The crystallization of the calcite from the copper mines of Lake Superior, by Charles Palache. Accompanied by six plates (100 extra printed separately).

ALFRED C. LANE, State Geologist.

Coal in Lower Michigan, by Alfred C. Lane, published serially in the Michigan Miner, Vol. I, Nos. 3 to 10, February to September, 1899, (500 reprints).
Annual Report for the year 1899. Michigan Miner, Vol. II, No. 3, February, 1900 (500 reprints stitched in with the following No.).
The Origin, Properties and Uses of Shale, by H. Ries, Special Agent for the State Geological Survey. Published in the Michigan Miner, Vol. I, No. 12, Vol. II, Nos. 1 and 2 (500 reprints).
The U. S. Survey have published Monographs of the Copper Bearing Rocks of Lake Superior, the Marquette Range, the Penokee Gogebic Range and other publications relative to the Geology of Michigan, for which address the Director, Washington, D. C. Also, Water Resources of the Lower Peninsula of Michigan, by Alfred C. Lane, Water Supply and Irrigation Paper No. 30, 1899.
Lower Michigan Mineral Waters, by Alfred C. Lane, Water Supply and Irrigation Paper No. 31, 1899.

The distribution of the reports of the Commissioner of Mineral Statistics was under the direction of the Board of G. S. from 1877-1883, since when they have been distributed by each Commissioner independently:

C. D. Lawton, of Lawton, 1883-91; J. P. Edwards, of Houghton, 1891-92; J. B. Knight, of Norway, 1893-95; George A. Newett, of Ishpeming, 1895-99; Jas. Russell, of Marquette, 1899.

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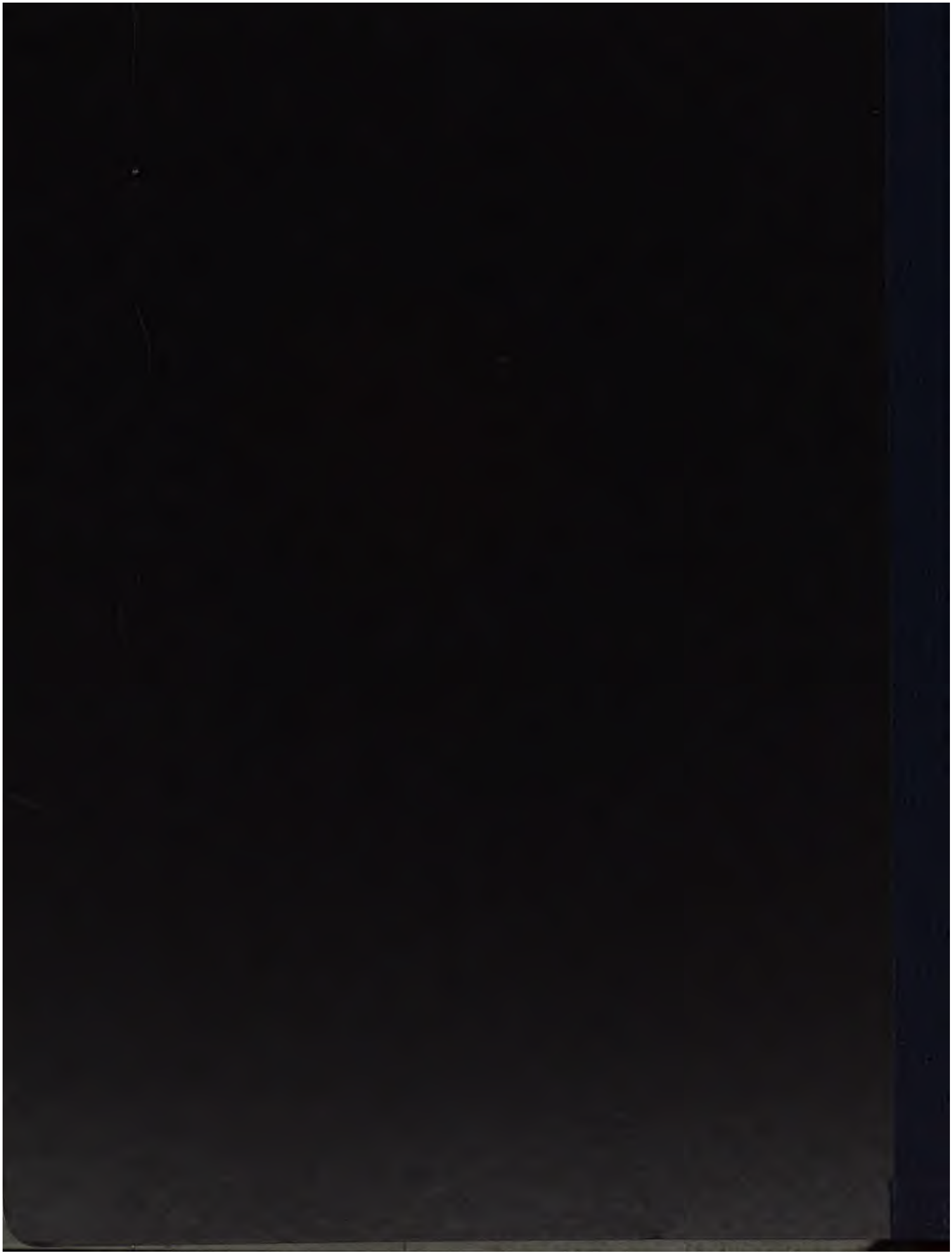
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